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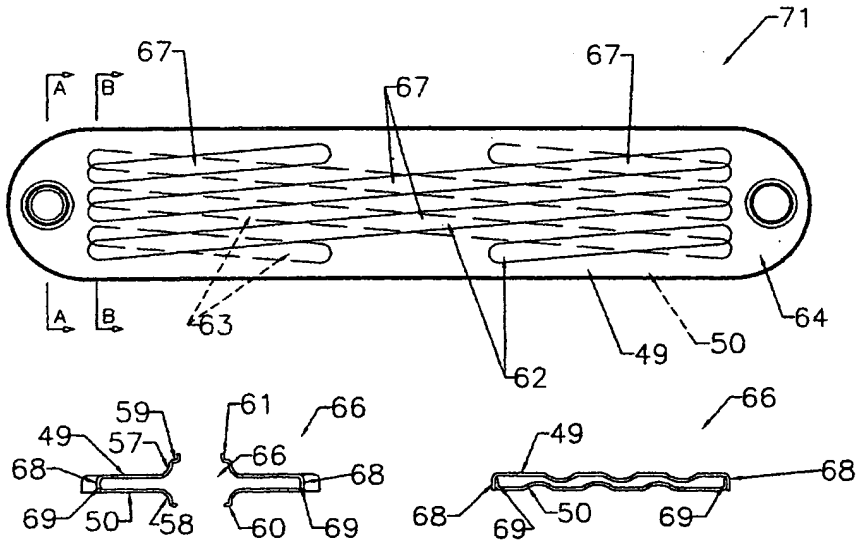
(54) Title: EXHAUST GAS COOLER



(57) Abstract: An exhaust gas cooler (70) for reducing the temperature of exhaust gases from internal combustion engines comprising a plurality of coolant passages (66) provided in a housing (20). The passages (66) may be formed by two opposing plates (49, 50) preferably with indentations in the form of ribs (62) thereon. The indentations on the opposing plates (49, 50) are preferably provided to form a criss-cross pattern on the passage causing turbulence of the coolant which flows therebetween and turbulence of gas contacting the outer faces of the plates increasing the performance of the cooler. Moreover the ribs (62) may provide a means to self jig the plates thereby reducing manufacturing complexity and cost. The housing (20) may also be in the shape of a cube or cuboid to facilitate a more efficient use of engine space.

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"Exhaust Gas Cooler"

This invention relates to an exhaust gas cooler for reducing the temperature of exhaust gases from internal combustion engines. In particular the invention relates to an exhaust gas cooler in which a coolant is passed around passages through which the exhaust gas travels.

Figs. 1a to 1c show a known exhaust gas cooler. This prior art cooler comprises a circular tube 1 which has tapered ends 2 which serve as entry 3 and exit 4 orifices for exhaust gases. The orifices are provided with flange plates 10 for connection to exhaust pipes. The ends of the tube are sealed by circular tube plates 5 which define a coolant chamber inside the tube. Each tube plate 5 has a number of circular holes 6 arranged through it. The holes 6 in each tube plate 5 are connected by a number of small diameter tubes 7 which are sealed at one end to the first tube plate and at the other end to the second tube plate. Exhaust gases flow into the entry orifice 3, along the inside of the

small diameter tubes 7 and out of the exit orifice 4. The exterior of the tube is provided with entry and exit nozzles 8, 9 which communicate with the coolant chamber for the supply of coolant liquid. A bracket 11 is fixed to the tube for mounting the exhaust gas cooler.

The manufacture of a heat exchanger containing a number of small diameter tubes is difficult and expensive. It is an object of the present invention to provide an exhaust gas cooler of comparable efficiency which can be manufactured more easily and cheaply without compromising cooling flow efficiency.

According to the present invention there is provided an exhaust gas cooler comprising:
a housing having an exhaust gas inlet at a first end and an exhaust gas outlet at a second end,
a plurality of spaced apart, coolant passages extending substantially parallel to each other within said housing, wherein each passage comprises two opposing plates and a side wall to couple the two opposing plates together such that the opposing plates form the top and bottom of the coolant passage, and coolant inlet and outlet means communicating with said plurality of coolant passages.

Preferably, the coolant passages are box-shaped.

Preferably each plate is provided with surface indentations in the form of ribs. Preferably the ribs extend diagonally across the surface of the plate.

Preferably the ribs of the first plate of each passage extend in a first skew direction and the ribs of the second plate of each passage extend in a second skew direction, such that the ribs of the first plate cross the ribs of the second plate. Preferably the ribs are formed as depressions in the plate surface towards the centre of the box. In one embodiment the ribs of the first plate of each passage are in contact with the ribs of the second plate of each passage at the points at which the ribs cross each other. Alternatively in another embodiment the first or second plate is provided with a depression adapted to contact the other of the first and second plates.

Preferably the side flange of each plate extends around the entire perimeter of the plate. Preferably the first and second plates of each passage are of such a size that the side flange of one of the plates fits within the side flange of the other of the plates. Preferably the side flanges are joined by brazing, welding, adhesive or similar to provide a fluid-tight joint between the plates.

Preferably the plates are pressed metal plates. The plates may be formed by hydroforming.

Preferably the ribs are formed as elongate depressions having a round or arcuate shape in cross section.

Preferably each plate is provided with a first aperture at its first end adapted to communicate with one of said coolant inlet and outlet means. Preferably each

plate is provided with a second aperture at its second end adapted to communicate with the other of said coolant inlet and outlet means. Preferably each aperture is surrounded by a sleeve portion adapted to engage with a sleeve portion on the adjacent plate of an adjacent passage to form a coolant conduit connecting the adjacent passages. Preferably the sleeve portion is provided on an opposite face of the plate to the side flanges.

Preferably the sleeve portion of one of the plates of each passage is adapted to fit within the sleeve portion of the other plate to provide a fluid-tight joint. The joint may be sealed by welding, brazing, adhesive or other sealant. In one embodiment the sleeve portions are shaped so as to hold adjacent passages in spaced apart relationship at a predetermined spacing, for example by providing a stepped formation on one sleeve portion against which the adjacent corresponding sleeve portion abuts. In another embodiment the at least one of first and second plates is provided with one or more outwardly extending depressions adapted to contact the second or first plate of the adjacent passage so as to hold adjacent passages in spaced apart relationship at a predetermined spacing.

Preferably the plurality of spaced apart, box-shaped coolant passages are in a stacked arrangement, the sleeve portions of the plates being aligned to form a continuous coolant conduit at each end of the housing. Preferably one end of each conduit communicates with

one of the coolant inlet and outlet means, while the other end of each conduit is closed off.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying figures, where:

Figs. 1a, 1b, and 1c are a side elevation, a partial sectional view on line A-A, and an end elevation of a prior art exhaust gas cooler;
Fig. 2 is a side sectional view through a first embodiment of an exhaust gas cooler according to the invention;
Fig. 3a is a plan view of an upper coolant passage plate of the exhaust gas cooler of Fig. 2;
Fig. 3b is a sectional view on the line A-A of the plate shown in Fig. 3a;
Fig. 3c is a sectional view on the line B-B of the plate shown in Fig. 3a;
Fig. 3d is a sectional view through a lower coolant passage plate of the exhaust gas cooler of Fig. 2, corresponding to the line A-A in Fig. 3a;
Fig. 3e is a sectional view through a lower coolant passage plate of the exhaust gas cooler of Fig. 2, corresponding to the line B-B in Fig. 3a;
Fig. 4a is a plan view of a coolant passage of the exhaust gas cooler of Fig. 2;
Fig. 4b is a sectional view on the line A-A of the coolant passage of Fig. 4a;

Fig. 4c is a sectional view on the line B-B of the coolant passage of Fig. 4a;

Fig. 5 is a sectional view on the line B-B of the exhaust gas cooler of Fig. 2;

Fig. 6 is a side view of a second embodiment of an exhaust gas cooler according to the invention, with the casing removed for clarity;

Fig. 7 is a side view of the exhaust gas cooler of Fig. 6 with the casing in place;

Fig. 8 is a plan view of a pair of coolant passage plates forming a coolant passage of the exhaust gas cooler of Fig. 6;

Fig. 9a is a sectional view on the line A-A of the coolant passage plates of Fig. 8;

Fig. 9b is a sectional view on the line B-B of the coolant passage plates of Fig. 8;

Fig. 9c is a sectional view on the line C-C of the coolant passage plates of Fig. 8;

Fig. 9d is a sectional view on the line D-D of the coolant passage plates of Fig. 8;

Fig. 10a is a plan view of a third embodiment of an exhaust gas cooler according to the invention;

Fig. 10b is an end view of the exhaust gas cooler of Fig. 10a;

Fig. 10c is a sectional view on the line A-A of the exhaust gas cooler of Fig. 10a;

Fig. 11 is a perspective view of the exhaust gas cooler of Fig. 10a showing coolant passages;

Fig. 12 is a second perspective view of the exhaust gas cooler of Fig. 10a;

Fig. 13a is an enlarged side view of an end portion of a passage of the exhaust gas cooler of Fig. 10a;

Fig. 13b is a side view of a passage of the exhaust gas cooler of Fig. 10a;

Fig. 13c is an enlarged side view of a second end portion of a passage of the exhaust gas cooler of Fig. 10a;

Fig. 13d is a plan view of the passage shown in Fig.13b;

Fig. 13e is an end view of section A-A of the passage shown in Fig. 13d;

Fig. 14a is a side view of a housing of the exhaust gas cooler shown in Fig. 10a with the top outer plate removed for clarity;

Fig. 14b is a plan view of the housing shown in Fig. 14a;

Fig. 15a is a plan view of the housing of the exhaust gas cooler of Fig. 10a with the top and bottom outer plate removed for clarity;

Fig. 15b is an end view of section A-A of the housing shown in Fig. 15a;

Fig. 15c is a side view of the housing shown in Fig. 15a;

Fig. 15d is an end view of section B-B of the housing shown in Fig. 15a;

Fig. 16a is an enlarged side view of an end portion of a top inner plate of the exhaust gas cooler of Fig. 10a;

Fig. 16b is a side view of the top inner plate of the housing of the exhaust gas cooler of Fig. 10a;

Fig. 16c is an enlarged side view of a second end portion of a top inner plate of the housing of the exhaust gas cooler of Fig. 10a;

Fig. 16d is a plan view of the top inner plate of Fig. 16b;

Fig. 16e is an end view on line A-A of the top inner plate of Fig. 16d;

Fig. 17a is a side view of a top outer plate of the exhaust gas cooler of Fig. 10a;

Fig. 17b is a plan view of the top outer plate of Fig. 17a;

Fig. 17c is an enlarged side view of section A-A of an end portion of the top outer plate of Fig. 17b;

Fig. 18a is a side view of a bottom outer plate of the exhaust gas cooler of Fig. 10a;

Fig. 18b is a plan view of the bottom outer plate of Fig. 18a; and,

Fig. 18c is an enlarged side view of section A-A of the bottom outer plate of Fig. 18b.

The exhaust gas cooler shown in Fig. 2 consists of an external tubular housing 20. At each end of the housing 20 are fixed tapered cap portions 25a, 25b which are adapted to fit over the end of the tubular housing and be fastened by suitable means such as welding. At the narrow end of the tapered cap portion 25a is a flange plate 26 provided with two holes 27 for attachment to a corresponding flange plate (not shown) in order to secure the cooler to an exhaust pipe or line (not shown). The flange plates 26 each contain a

larger hole which serves as an entry 28 or exit 29 orifice for gas.

A number of box-like coolant passages or tubes 66 extend along the tubular housing in a parallel stacked arrangement. Each passage comprises two plates 49, 50 are aligned with the longitudinal axis of the tubular housing 20. The plates are provided as pairs 71 with an upper 49 and lower 50 plate forming a tube 66. The plate pairs 71 are parallel with respect to each other.

Figs. 3a to 3e show the plates 49, 50 in more detail. The plates are generally rectangular in plan, with rounded ends 51, 52 and straight sides 53, 54. The upper plate 49 is provided with a downwardly extending flange 68 around its perimeter, while the lower plate 50 is provided with an upwardly extending flange 69 around its perimeter. The lower plate 50 is smaller than the upper plate 49, so that the lower flange 69 fits securely inside the upper flange 68. The flanges 68, 69 are sealed by any suitable means, for example by brazing, welding or adhesive, so that the two plates 49, 50 form a fluid-tight passage or tube 66.

Circular apertures 55, 56 are provided in the plates 49, 50 to allow water or any other coolant liquid to flow into one end of the tube 66, along the tube, and out the other end. Circular tapered sleeve portions 57 extend upwardly at each end from each upper plate 49, while circular tapered sleeve portions 58 extend downwardly at each end from each lower plate 50. Lip portions 59, 60 are present on the edge of each tapered

portion 57, 58 and extend parallel to the main plane of the plate 49, 50. An upwardly extending flange 61 is provided on the lip portion 59 of the upper plate 49 which is designed to correspond with the lip portion 60 of a lower adjacent plate 50. In this way a lower plate 50 can be stacked on top of an upper plate 49, such that the flange 61 engages inside the lip 60, which will abut the lip 59 and hold the upper and lower plates apart in a predetermined spacing, thereby providing a passage between the coolant tubes 66 for the flow of exhaust gas.

Alternatively the flange portion 61 may be located on the lip portion 60 of the lower plate 50 adapted to correspond with the lip portion 59 on an upper adjacent plate 49.

On the planar surface 64, 65 of the plates 49, 50 are diagonally extending grooves or ribs 62, 63.

Figs. 4a to 4c show a pair of plates 49, 50 joined together to form a tube 66. To join, a pair of plates 49, 50 are pressed together so the circumferential flanges 68, 69 fit inside each other as shown in Figs. 4b and 4c. The diagonal grooves or ribs 62, 63 extend in opposite diagonal directions to form a criss-cross configuration as shown in Fig. 4a. At the crossover points 67 the ribs 62 of the upper plate 49 are in contact with the ribs 63 of the lower plate 50, so that the plates 49, 50 cannot be pressed together further. Thus the grooves serve as a jig which ensures that the plates are automatically at the correct spacing when

they are assembled together. The ribs or grooves 62, 63 also serve to increase the turbulence inside and outside the tube 66 which benefits the performance of the exhaust gas cooler.

During assembly the tubes 66 can be inserted into the body 20 before the tube cap 25a is secured. Adjacent tubes 66 connect with each other at the tapered sleeve portions 57, 58 and engage by means of the lip portions 59, 60 and the lip flange 61 as shown in Fig. 5, and as described above. The connection between adjacent sleeve portions can be sealed by any appropriate means, including welding, brazing, solder, adhesive etc. The top sleeve portion 57' engages with the coolant inlet 33, while the bottom sleeve portion 58' is closed off with a blanking plate. Equivalent connections are made at the end of the housing with the coolant outlet 34.

When the assembly is complete exhaust gases flow into the entry orifice 28, and into the body 20 of the exhaust gas cooler 70. The gases flow past the tubes 66 and then through the outlet 29.

A further embodiment of an exhaust gas cooler according to the invention is shown in Figs. 6 to 9. The same reference signs are used to indicate components which are common to the embodiment illustrated in Figs. 2 to 5. The cooler has an external tubular casing 120. The casing is formed in two halves 120a, 120b which are joined at an overlap 121. The casing is substantially rectangular in cross section. At each end of the casing 120 there is an end wall 122 which has a tubular

passage 123 opening to a flange plate 26 provided with two holes 27 for attachment to a corresponding flange plate (not shown) in order to secure the cooler to an exhaust pipe or line (not shown). The flange plates 26 each contain a larger hole which serves as an entry 28 or exit 29 orifice for the exhaust gas.

As in the first embodiment, a number of box-like coolant passages or tubes 166 extend along the tubular housing in a parallel stacked arrangement. Each passage comprises two plates 149, 150 arranged parallel to each other and to the longitudinal axis of the tubular housing 120. The plates are provided as pairs 171 with an upper 149 and lower 150 plate forming a tube 166. The pairs 171 of plates are arranged parallel to each other.

Figs. 8 and 9a to 9d show the plates 149, 150 in more detail. The plates are generally rectangular in plan, with rounded ends 51, 52 and straight sides 53, 54. The upper plate 149 is provided with a downwardly extending flange 168 around its perimeter, while the lower plate 150 is provided with an upwardly extending flange 169 around its perimeter. The lower plate 150 is larger than the upper plate 149, so that the upper flange 168 fits securely inside the lower flange 169. The flanges 168, 169 are sealed by any suitable means, for example by brazing, welding or adhesive, so that the two plates 149, 150 form a fluid-tight passage or tube 166.

Circular apertures 55, 56 are provided in the plates 149, 150 to allow water or any other coolant liquid to flow into one end of the tube 166, along the tube, and out the other end. Circular sleeve portions 157a, 157b extend upwardly at each end from each upper plate 149, while circular sleeve portions 158a, 158b, adapted to fit within or around sleeves 157a, 157b, extend downwardly at each end from each lower plate 150.

The lower plate 150 is provided with an upwardly extending circular depression 159, which engages with the upper plate 149 when the upper plate 149 is placed inside the lower plate 150, to hold the upper and lower plates apart in a predetermined spacing, typically 3 to 6 mm, thereby providing a coolant tube 166. The depression 159 may be connected by a spot weld 160. Additional spot welding may be provided, together with additional depressions 159, if required. The spot welding may be omitted if a fluid tight tube is achieved by secure interconnection of the upper and lower plates 149, 150 at their perimeters and/or openings 55, 56.

On the planar surface of the plates 149, 150 are diagonally extending grooves or ribs 162, 163, formed as depressions outwards from the other of the pair of plates 149, 150. The ribs 162, 163 extend in opposite diagonal directions to form a criss-cross configuration, as described above with reference to Figs. 2 to 5. However the ribs 162, 163 do not have to serve as a jig to control the spacing of the plates 149, 150, since this function is served by the

depression 159. The ribs 162, 163 serve to increase the turbulence inside and outside the tube 166. If desired the ribs 162, 163 may be reversed in direction so that they are formed as inward depressions. The rib pattern may be varied.

Spacing indentations 170 which extend upwardly in the upper plate 149 and downwardly in the lower plate 150 are provided at six locations. The number of locations may be varied. These serve to space apart the pairs 171 of plates when they are stacked, thereby permitting the passage of exhaust gases between the pairs 171 of plates. The spacing 190 between adjacent pairs is typically between 3 and 6 mm.

In the example shown in Figs. 6 and 7 the upper plate of the upper passage 166 is formed from a plane plate 201 which forms part of the casing 120. Similarly the lower plate of the lower passage 166 is formed from a plane plate 202 which forms part of the casing 120. These plane plates 201, 202 extend beyond the other plates 149, 150. The plane plates 201, 202 may be provided with ribs.

The coolant inlet 33 and coolant outlet 34 join at opposite ends of the body 20 or casing 120. In the embodiment illustrated both the inlet and outlet pipes 33, 34 incorporate a 90° bend, so that the hose connections to the ends 35 of the pipes 33, 34 may be made parallel to the longitudinal axis of the body 20 or casing 120. It is to be understood that either of the inlet or outlet pipes 33, 34 may be straight so

that the hose connections to the ends 35 may be made perpendicular to the longitudinal axis 50 of the tube, or that either of the inlet or outlet pipes 33, 34 may incorporate a bend of an intermediate angle less than 90°. Either of the inlet or outlet pipes 33, 34 may be reversed so that the open end 35 faces towards the centre of the exhaust gas cooler, instead of facing away from the centre of the exhaust gas cooler as shown in Fig. 2.

The efficiency of the tubes 66 alleviates the need for additional cooling fins. The grooves 62, 63 provide a means for self jigging the pair of plates 49, 50 which make up the tube 66, and so simplify the assembly of the exhaust gas cooler in addition to increasing the exhaust gas and coolant liquid turbulence.

Although the grooves or ribs 62, 63 are illustrated as arc-shaped in cross-section, it is to be understood that other shapes can be used, for example, U-shape, V-shape, trapezoidal, rectangular, semi-circular etc.

The plates 49, 50, 149, 150 are easy to manufacture and assemble compared with small diameter tubes used in the prior art, since they can be made as simple sheet pressings.

Although the plates 49, 50, 149, 150 of the cooler are shown as pressings, the passages or tubes 66, 166 may be manufactured by any suitable method, for example by hydroforming.

A third preferred embodiment of a gas cooler is shown in Figs. 10-18. The same reference numerals have been used for the third embodiment as were used for the previous embodiments but, in this case, preceded by a '2'.

The cooler has a housing 220 with an internal substantially rectangular shaped cross-section bore and an external substantially rectangular shaped cross section; alternatively the housing 220 may be formed with a substantially oval-shape cross-section. Five tubes 266 are arranged within the housing as described for previous embodiments, although it will be appreciated that any number of tubes may be included in the housing.

The tubes 266 are formed from transforming a cylindrical tube into the oval-like passage by any suitable means, for example, by compression of the cylindrical tube within a suitably sized mould. Thus the manufacturing process may be simplified further in that the plates 249, 250 which form the tube 266 may be formed integrally from a one piece tube instead of two separate plates. Thus, in this preferred third embodiment, the tubes 266 comprise top 249 and bottom 250 plates which oppose each other, and a side wall 268 to couple the two opposing plates 249, 250 together.

Figs. 11, 12 show the third embodiment in perspective view comprising the housing 220 with a flange 226 at each end thereof, a coolant inlet 233, coolant outlet 234, a top inner plate 280 (not shown in Figs. 11, 12),

a top outer plate 280, a bottom outer plate 290 (not shown in Figs. 11, 12) and the five tubes 266. The skilled reader will realise that the coolant inlet 233 could alternatively be configured to be a coolant outlet 233, and the coolant outlet 234 could alternatively be configured to be a coolant inlet 234.

The passages 266 are shown in more detail in Fig. 13a-13e. On the planar surface of the plates 249, 250 are diagonally extending grooves or ribs 262, 263 formed as depressions outwards from the other of the pair of plates 249, 250. The ribs extend in opposite diagonal directions to form a criss-cross configuration, as described above with reference to previous embodiments. The ribs 262, 263 do not have to serve as a jig to control the spacing of the plates 249, 250, since this function is served by a depression 259 or a sleeve 255. The ribs 262, 263 and in particular the criss-cross configuration of the ribs 262, 263 serve to increase the turbulence of the coolant inside the passages 266 and the exhaust gas outside the passages 266 thereby helping to increase the efficiency of the exhaust gas cooler. If desired the ribs may be reversed in direction so that they are formed as inward depressions. The rib pattern may be varied.

The housing 220 in shown in more detail in Figs. 14a, 14b and particularly Figs 15a-d. An inwardly extending portion 291 is provided at the bottom of the housing 220. The bottom outer plate 290 (shown in Figs. 18a-18e) is attached to the outer face of the bottom of the housing 220, thus forming a further passage 292 for

coolant to flow through between the inwardly extending portion 291 of the housing and the bottom outer plate 290. Apertures 355 and sleeve portions 359 are provided to connect the further passage 292 with the passages 266 as described for the inter-passage connections of previous embodiments.

The inwardly extending portion 291 has ribs 362 running along the bottom of the housing 220. A criss-cross pattern is formed between the ribs 362 of the bottom of the housing 220 and the ribs 263 on the lower plate 250 of the lowermost passage 266'' causing increased turbulence of the exhaust gas flowing therethrough.

The top inner plate 295, shown in Figs. 16a-16e, has an inwardly extending portion 296 and connects via aperture 455 to the sleeves 257 of the upper plate 249 of the uppermost passage 266' as previously described above with respect to the lower inner plate 290. An upper outer plate 280 is attached at the top of the housing 220 and provides for a further coolant passage 297 between top outer 280 and top inner 295 plates. Thus coolant may flow to and from the further coolant passage 297 and the coolant passages 266 via the connection between the aperture 455 and the sleeve 257.

The upper inner plate 295 has ribs 463 extending further inwards towards the uppermost passage 266'. The ribs 463 run in a diagonal pattern as shown in Fig. 16d. Normally the ribs 463 will form a criss-cross pattern with the ribs 262 of the upper plate 249 of the

uppermost tube 266' thereby increasing turbulence of the exhaust gas passing therebetween.

Thus there are a total of seven coolant passages in the third embodiment, five formed from the plates 249, 250 and one at the top of the housing 220 formed between the top outer 280 and top inner 295 plates and one at the bottom of the housing 220 formed between the bottom of the housing and the bottom outer plate 290.

The shape of the body 220 is preferably rectangular which allows a more efficient use of space within an engine.

The exhaust gas flow is open, with minimal obstructions, so that fouling of the exhaust gas cooler is minimised.

The exhaust gas cooler of the present invention is manufactured from components which are themselves cheap and easy to manufacture and straightforward to assemble, since no separate jigging of the component parts is necessary.

In alternative embodiments a corrugated sheet may be provided between the passages 266 in order to increase the turbulence of the exhaust gas flow thereby increasing the efficiency of the exhaust gas cooler. In such embodiments the sheet has an aperture at each end to be placed around the sleeves 257 of the plates 249, 250. The corrugated sheet thus provides a fluid flow interruption mechanism.

These and other modifications and improvements can be incorporated without departing from the scope of the invention.

Claims

1. An exhaust gas cooler comprising:
a housing having an exhaust gas inlet at a first end and an exhaust gas outlet at a second end,
a plurality of spaced apart, coolant passages extending substantially parallel to each other within said housing, wherein each passage comprises two opposing plates and a side wall to couple the two opposing plates together such that the opposing plates form the top and bottom of the coolant passage, and coolant inlet and outlet means communicating with said plurality of coolant passages.

2. An exhaust gas cooler as claimed in claim 1, wherein each plate is provided with surface indentations, and each coolant passage is one of box- and oval-shaped.

3. An exhaust gas cooler as claimed in claim 2, wherein the surface indentations are in the form of ribs.

4. An exhaust gas cooler as claimed in claim 3, wherein the ribs extend diagonally across the surface of each plate.

5. An exhaust gas cooler as claimed in claims 3 or 4, wherein the ribs are formed as depressions in the plate surface towards the centre of the coolant passage.

6. An exhaust gas cooler as claimed in one of claims 3 to 5, wherein ribs of the first plate of each passage extend in a first skew direction and ribs of the second plate of each passage extend in a second skew direction, such that ribs of the first plate cross ribs of the second plate.

7. An exhaust gas cooler as claimed in claim 6, wherein ribs of the first plate of each passage are in contact with ribs of the second plate of each passage at the points at which the ribs cross each other.

8. An exhaust gas cooler as claimed in any preceding claim, wherein the first or second plate of a first passage is provided with a depression adapted to contact a first or second plate of a second passage so as to hold adjacent passages in spaced apart relationship at a predetermined spacing.

9. An exhaust gas cooler as claimed in any preceding claim, wherein the side wall of each passage extends around the entire perimeter of the passage.

10. An exhaust gas cooler as claimed in any preceding claim, wherein the side walls are provided on each opposing plate interengaging with one another, and the opposing plates of each passage are of such a size that the side flange portion of one

of the plates fits within the side flange portion of the other of the plates.

11. An exhaust gas cooler as claimed in any preceding claim, wherein the plates are pressed metal plates.

12. An exhaust gas cooler as claimed in any preceding claim, wherein the plates are formed by hydroforming.

13. An exhaust gas cooler as claimed in any of claims 2-12, wherein the ribs are formed as elongate depressions having an arcuate shape in cross section.

14. An exhaust gas cooler as claimed in any preceding claim, wherein each plate is provided with a first aperture at its first end adapted to communicate with one of said coolant inlet and outlet means.

15. An exhaust gas cooler as claimed in claim 14, wherein each plate is provided with a second aperture at its second end adapted to communicate with the other of said coolant inlet and outlet means.

16. An exhaust gas cooler as claimed in claim 14 or claim 15, wherein each aperture is surrounded by a sleeve portion adapted to engage with a sleeve portion on an adjacent plate of an adjacent passage

to form a coolant conduit connecting the adjacent passages.

17. An exhaust gas cooler as claimed in claim 16 when dependent on claim 10, wherein the sleeve portion is provided on an opposite face of the plate to the side flanges.

18. An exhaust gas cooler as claimed in claim 16 or claim 17, wherein the sleeve portion of one of the plates of each passage is adapted to fit within the sleeve portion of the other plate of another passage to provide a fluid-tight joint.

19. An exhaust gas cooler as claimed in any of claims 16 to 18, wherein the sleeve portions are shaped so as to hold adjacent passages in spaced apart relationship at a predetermined spacing.

20. An exhaust gas cooler, as claimed in claim 19, wherein a stepped formation is provided on one sleeve portion against which an adjacent corresponding sleeve portion of an adjacent plate of an adjacent passage abuts so as to hold the adjacent passages in spaced apart relationship at a predetermined spacing.

21. An exhaust gas cooler, as claimed in claim 8 or claim 20 or to one of claims 9 to 19 when dependent on claim 8, wherein the plurality of spaced apart, coolant passages are in a stacked arrangement.

22. An exhaust gas cooler, as claimed in any one of claims 16 to 21 when dependent on claim 16, wherein the sleeve portions of the plates are aligned to form a continuous coolant conduit at each end of the housing.

23. An exhaust gas cooler as claimed in claim 22, wherein one end of each conduit communicates with one of the coolant inlet and outlet means, while the other end of each conduit is closed off.

24. An exhaust gas cooler, as claimed in any preceding claim, wherein the housing has a square, oval or rectangular cross section.

25. An exhaust gas cooler as claimed in any one of claims 3 or 4, wherein the ribs are formed as depressions in the plate surface away from the centre of the coolant passage.

26. An exhaust gas cooler as claimed in any preceding claim, wherein a fluid flow interruption mechanism is provided between the coolant passages.

27. A method of manufacturing the coolant passages as claimed in any preceding claim, wherein a tube is compressed to form the coolant passages.

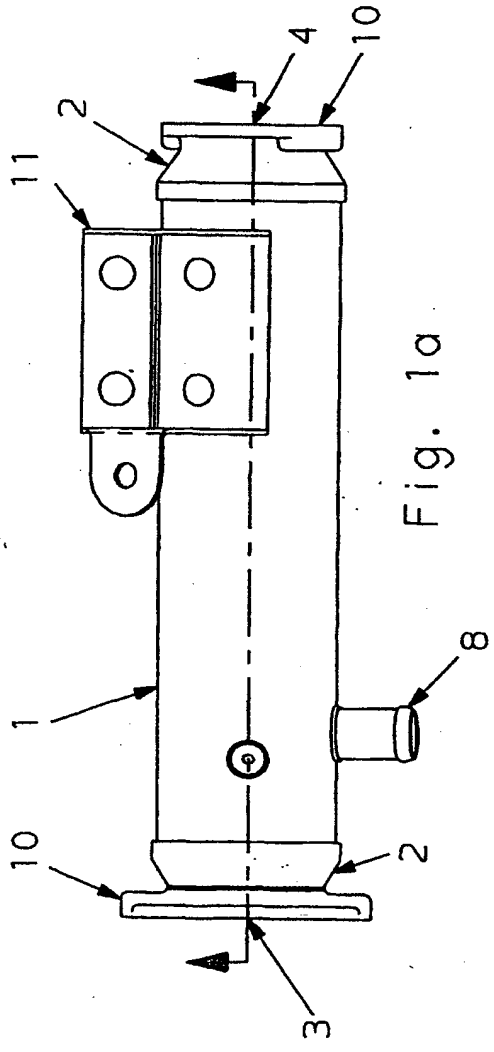


Fig. 1a

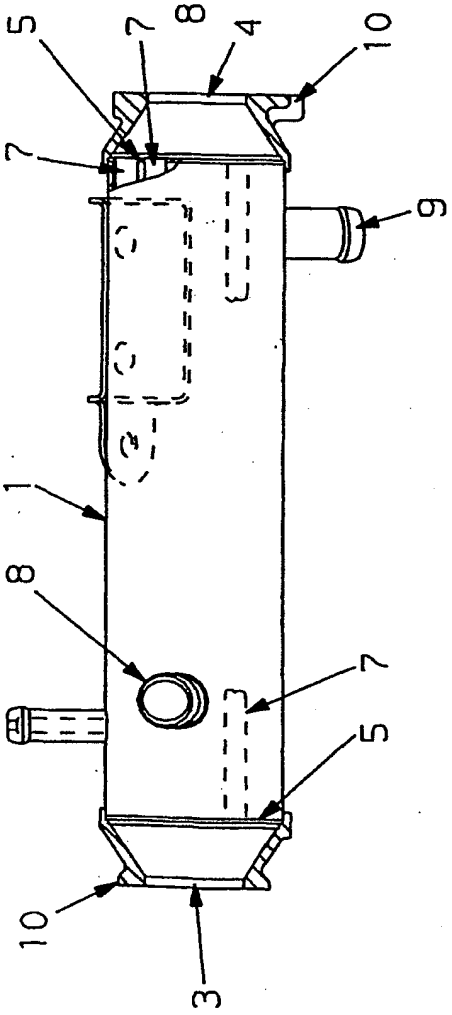


Fig. 1b

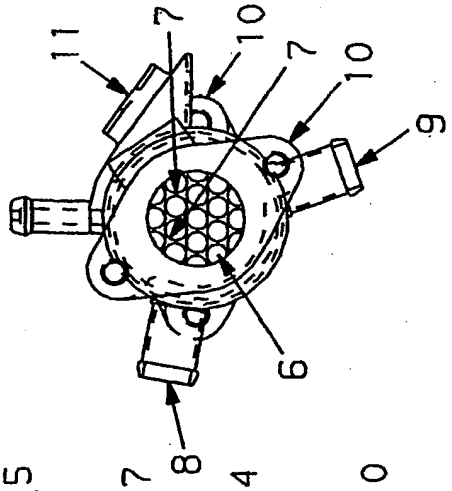


Fig. 1c

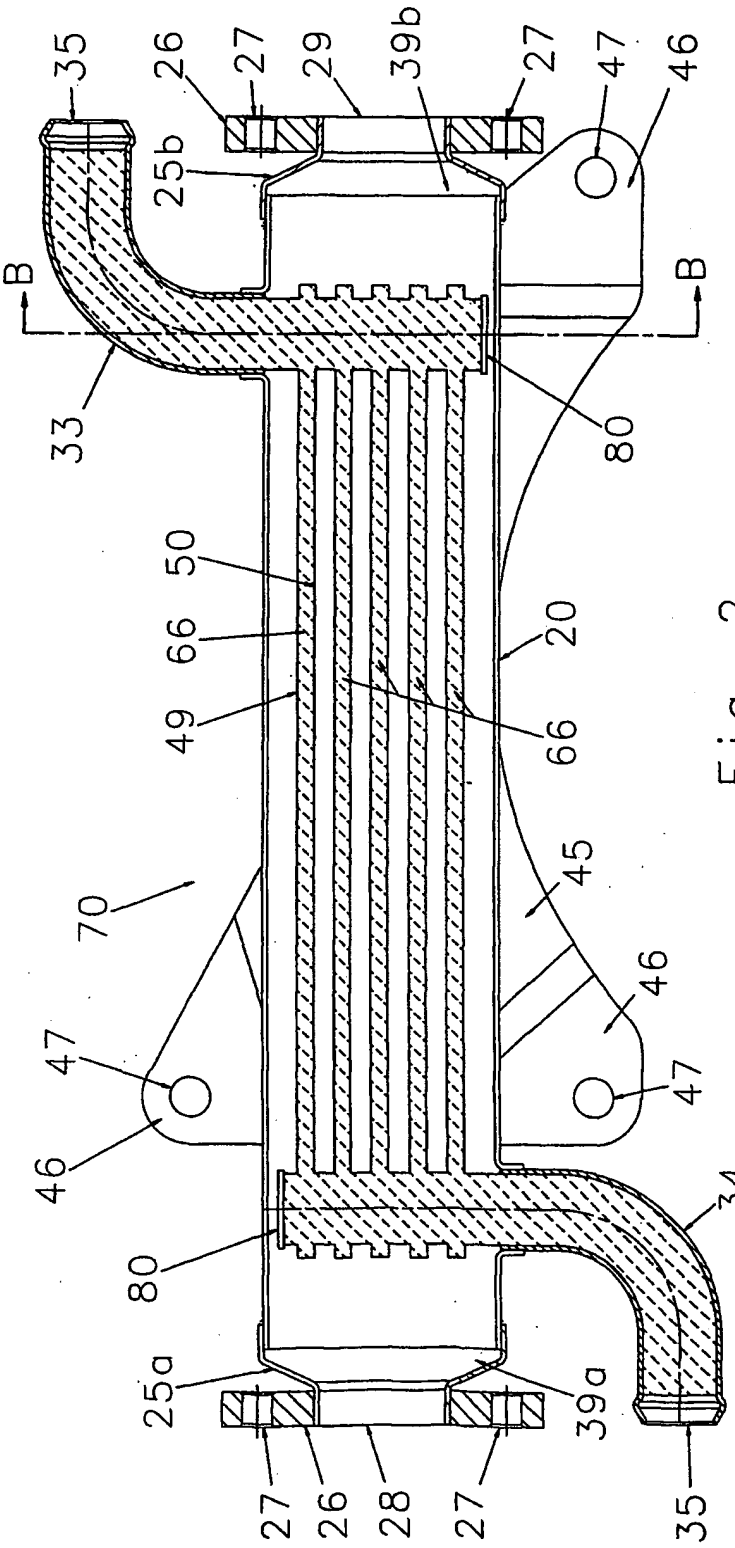


Fig. 2

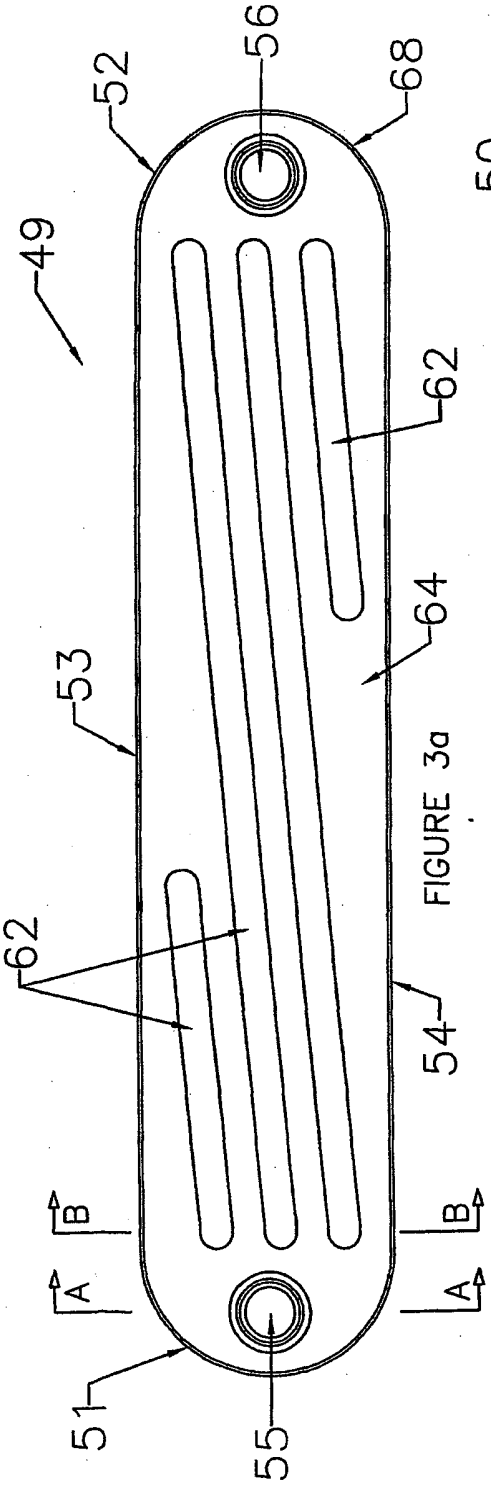


FIGURE 3a

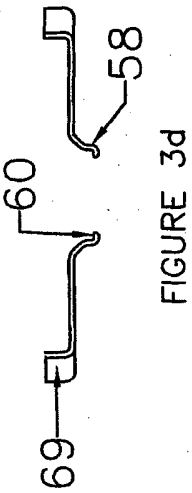


FIGURE 3d

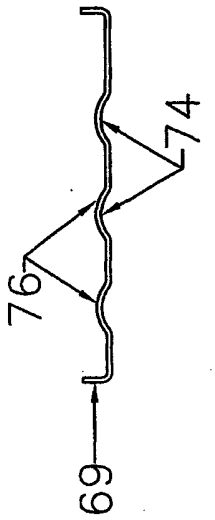


FIGURE 3e

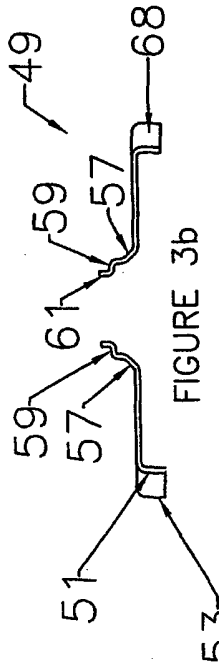


FIGURE 3b

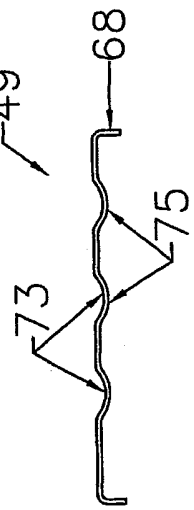


FIGURE 3c

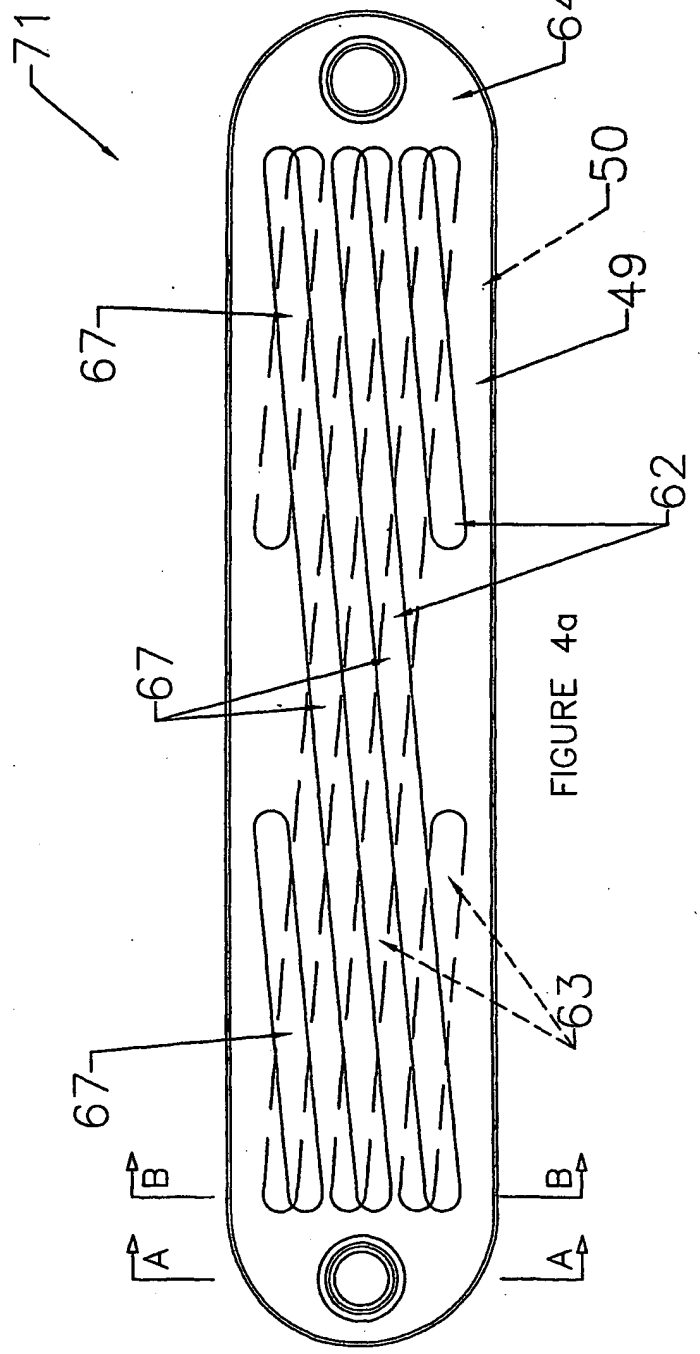


FIGURE 4a

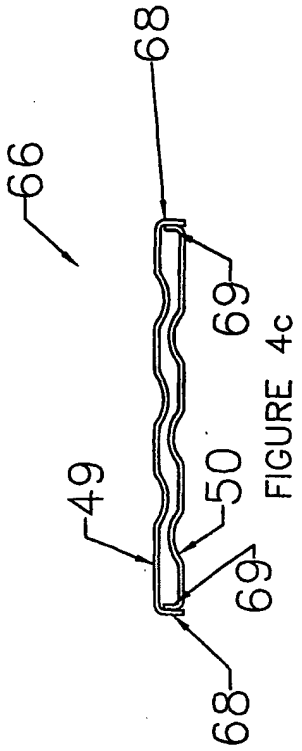


FIGURE 4c

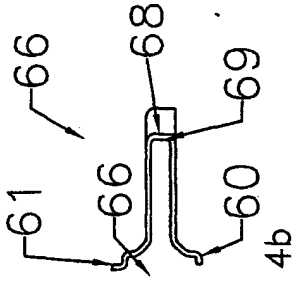


FIGURE 4b

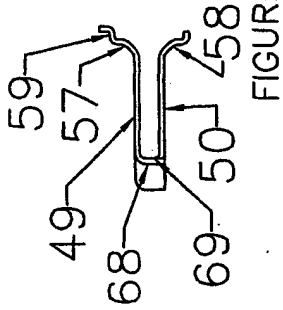


FIGURE 4d

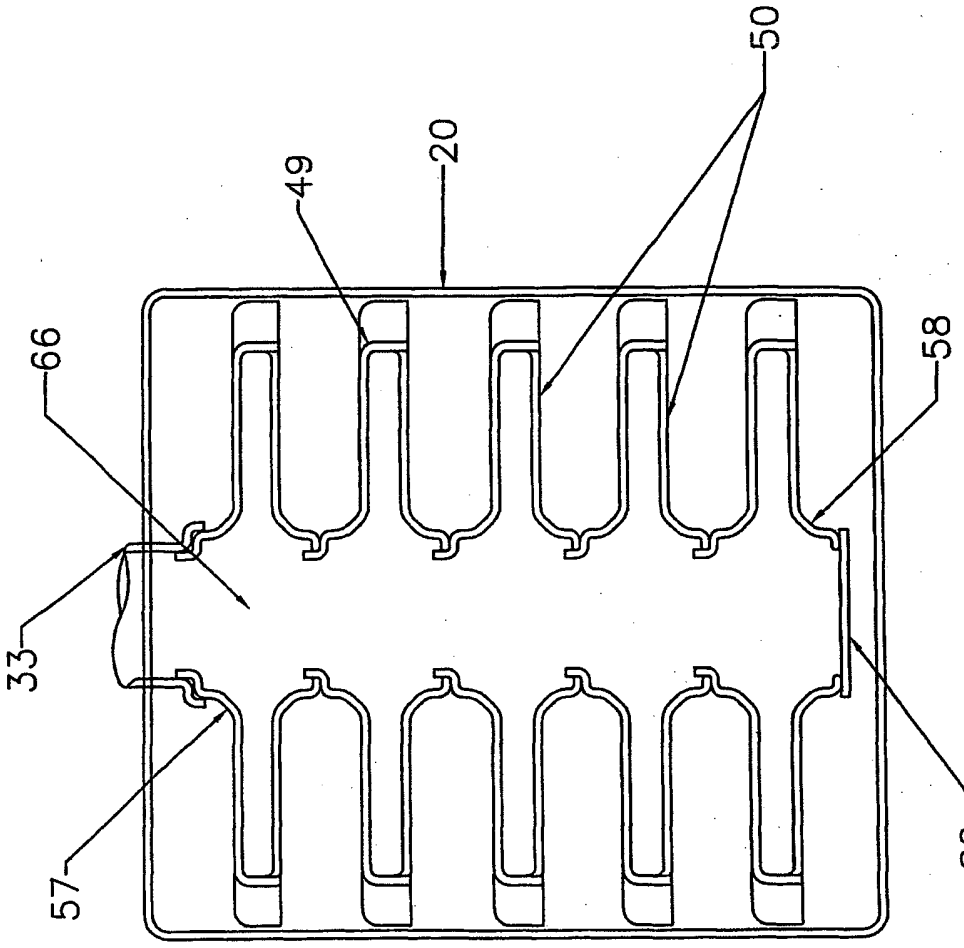


FIGURE 5

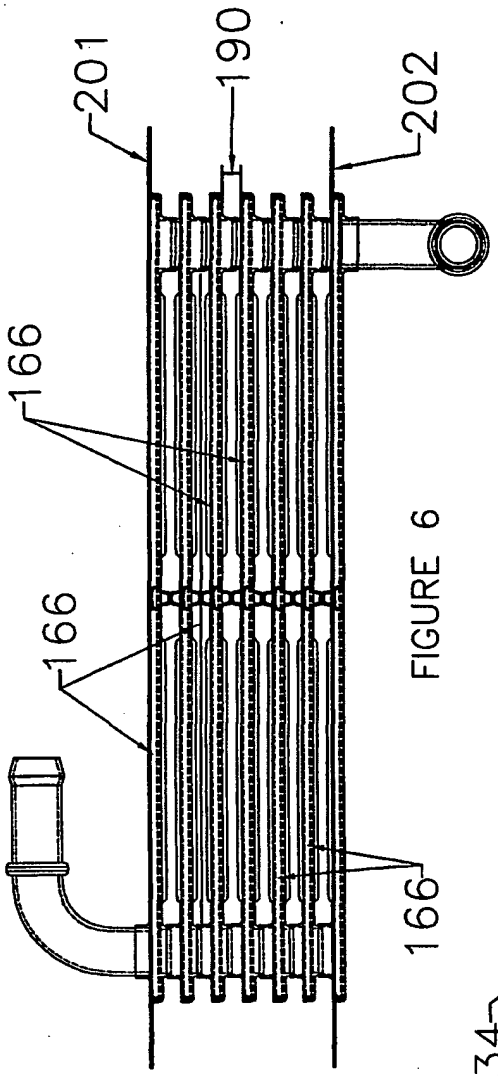


FIGURE 6

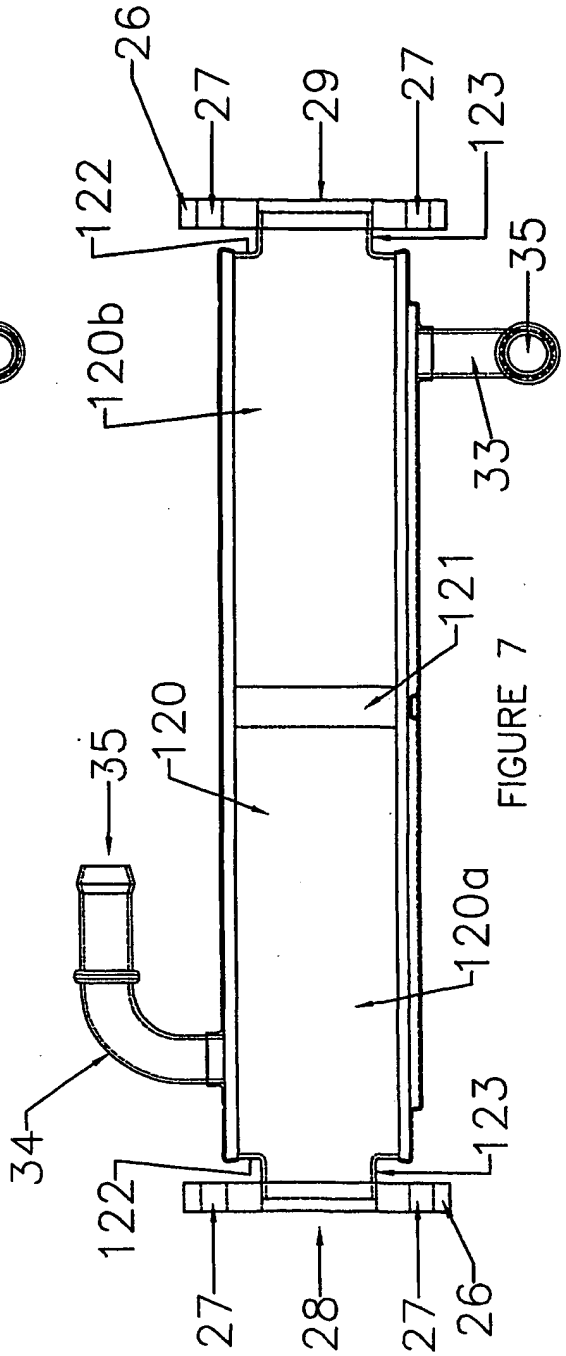


FIGURE 7

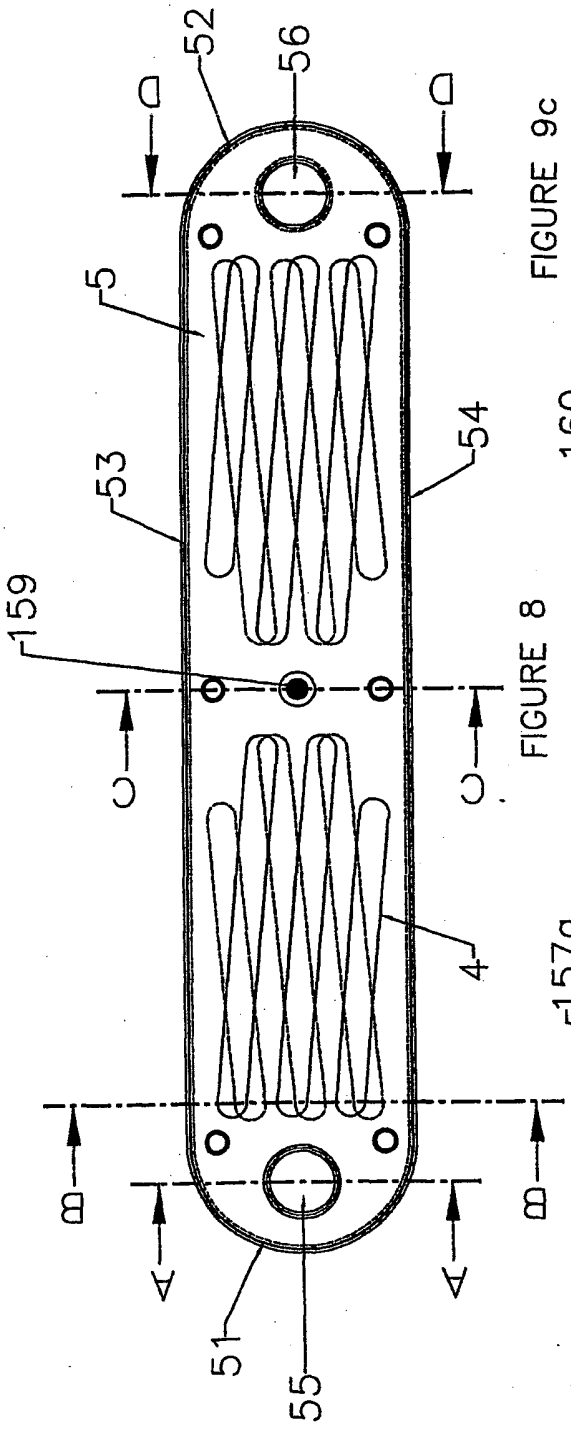
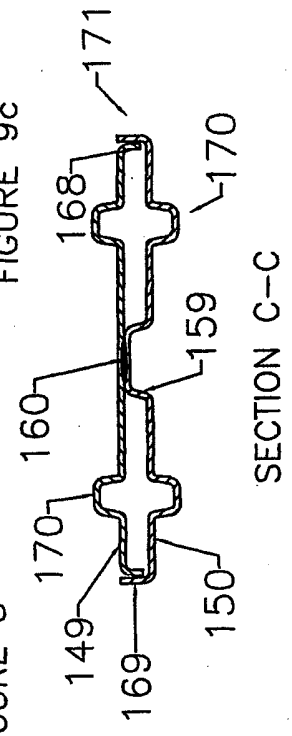
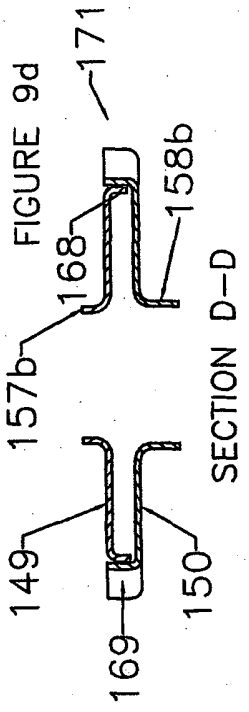


FIGURE 8



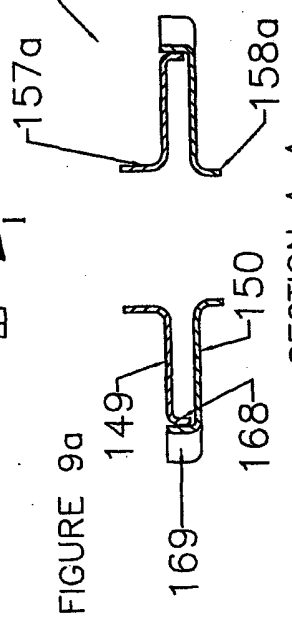
SECTION C–C

FIGURE 9c



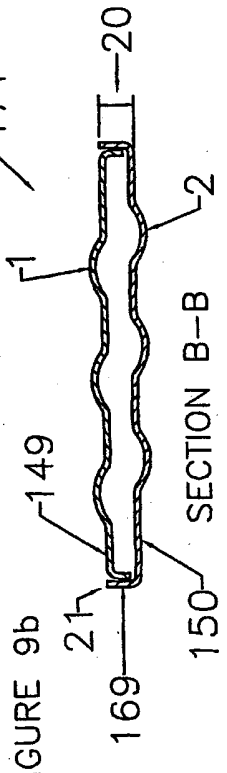
SECTION D–D

FIGURE 9d



SECTION A–A

FIGURE 9a



SECTION B–B

FIGURE 9b

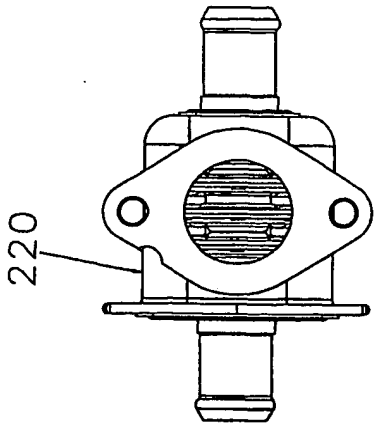


Fig. 10b

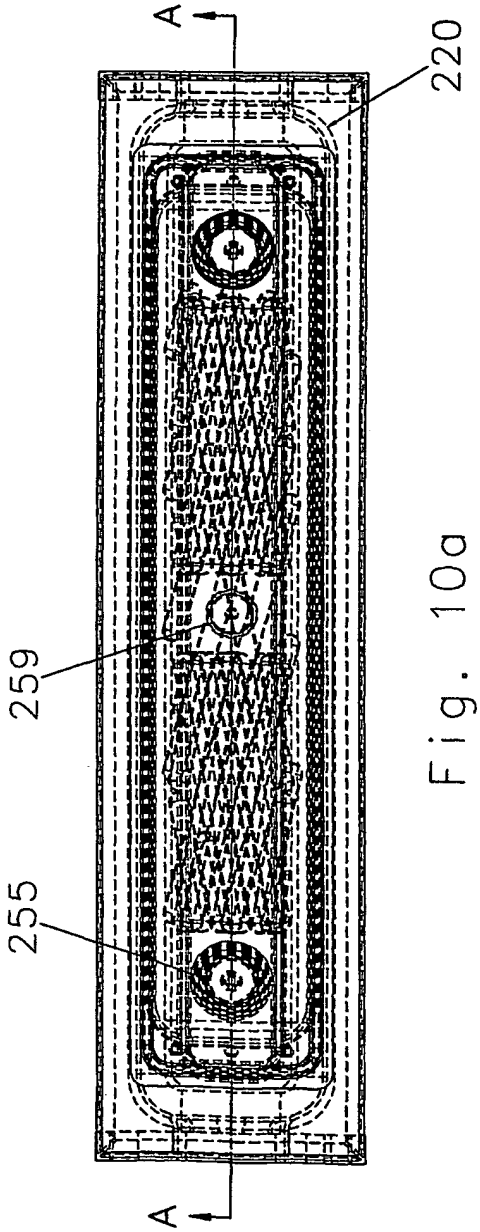


Fig. 10a

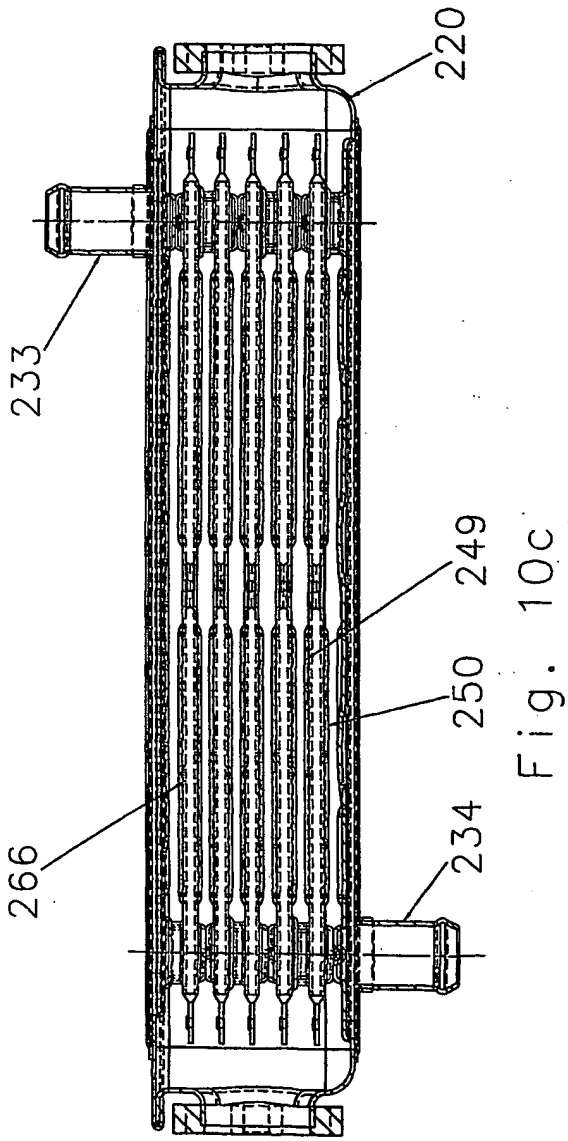


Fig. 10c

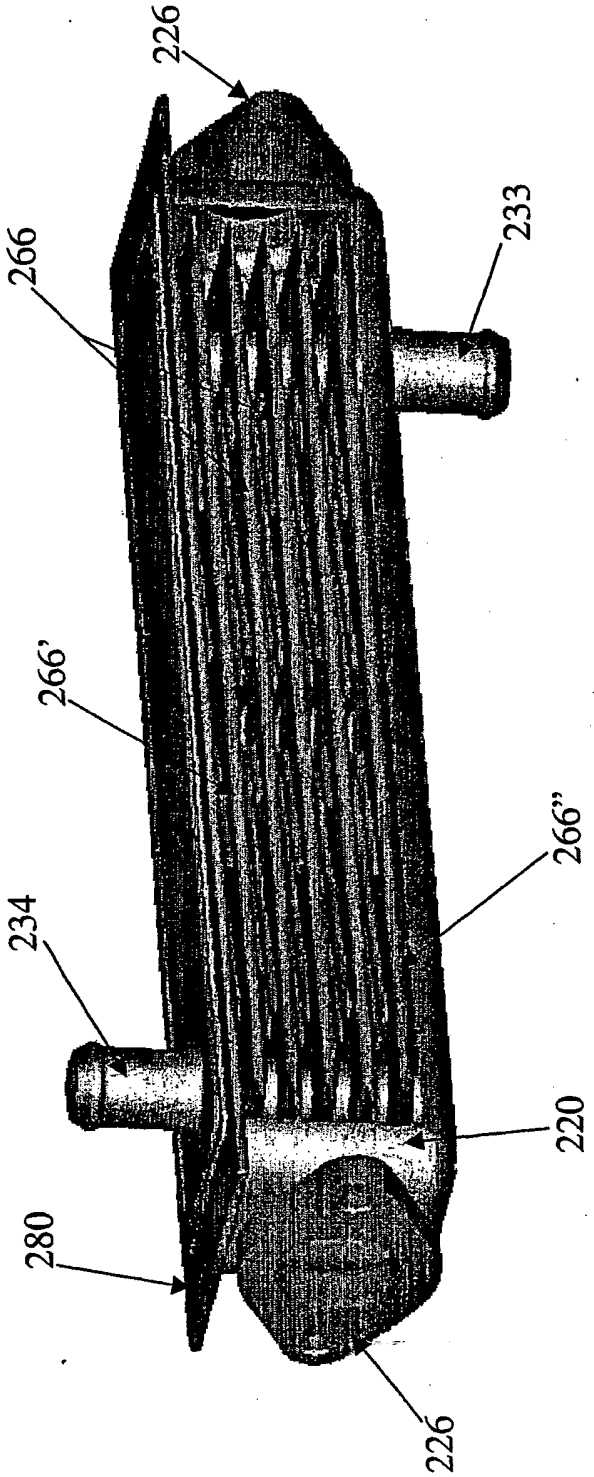


FIG 11

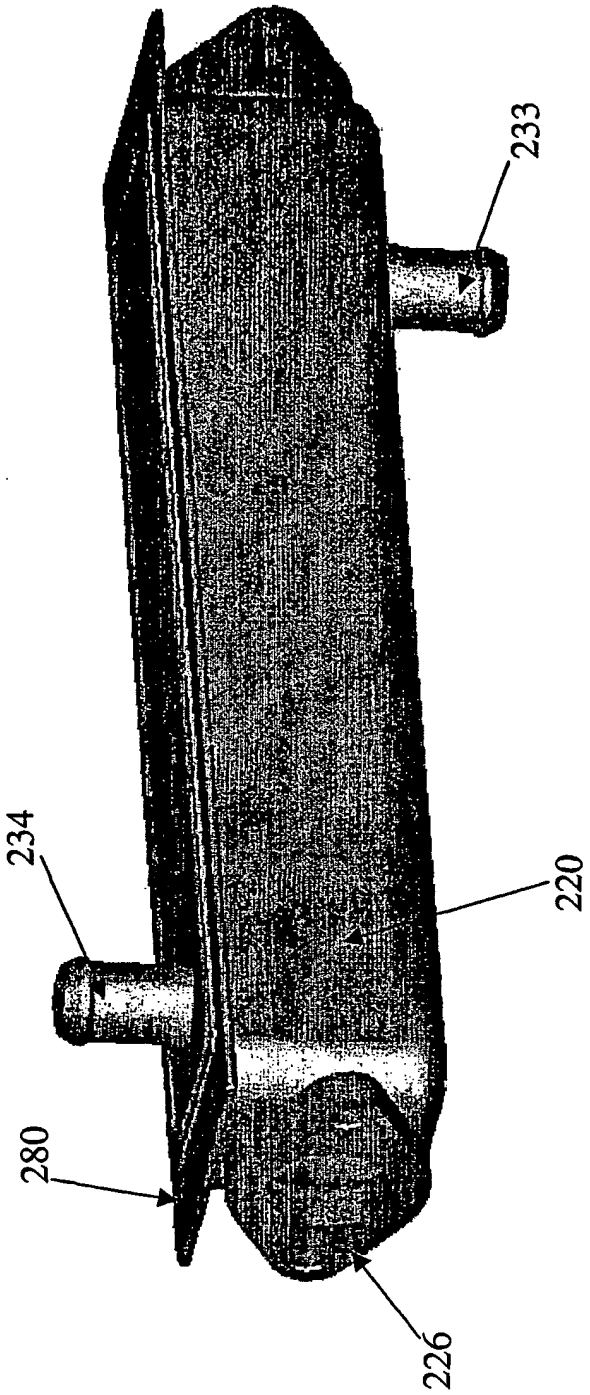


FIG 12

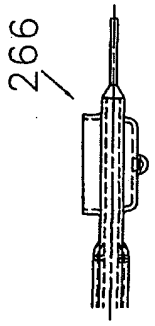


Fig. 13c

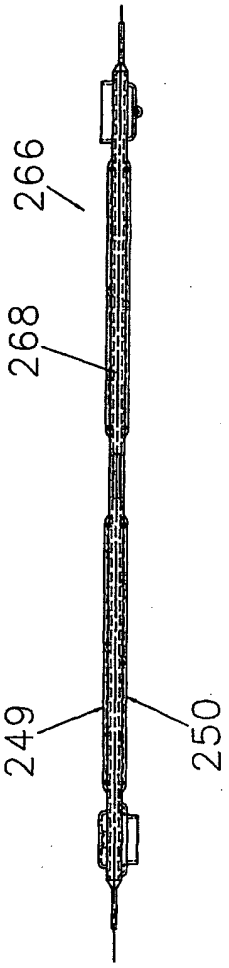


Fig. 13b

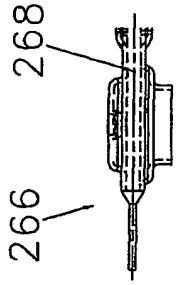


Fig. 13a

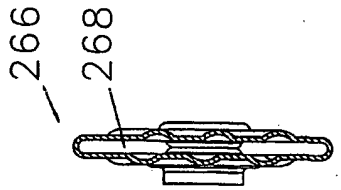


Fig. 13e

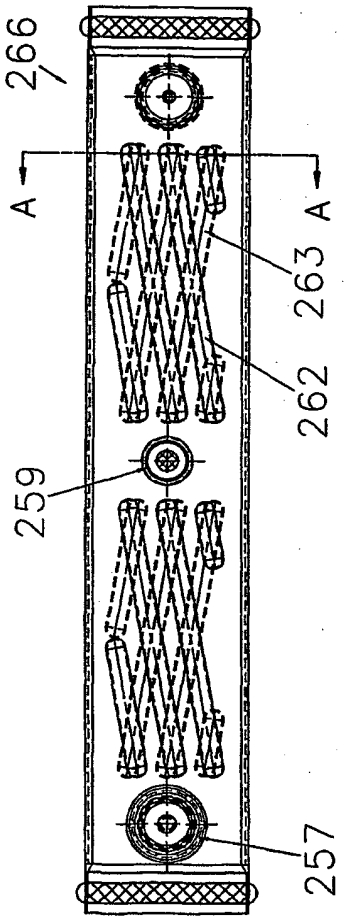


Fig. 13d

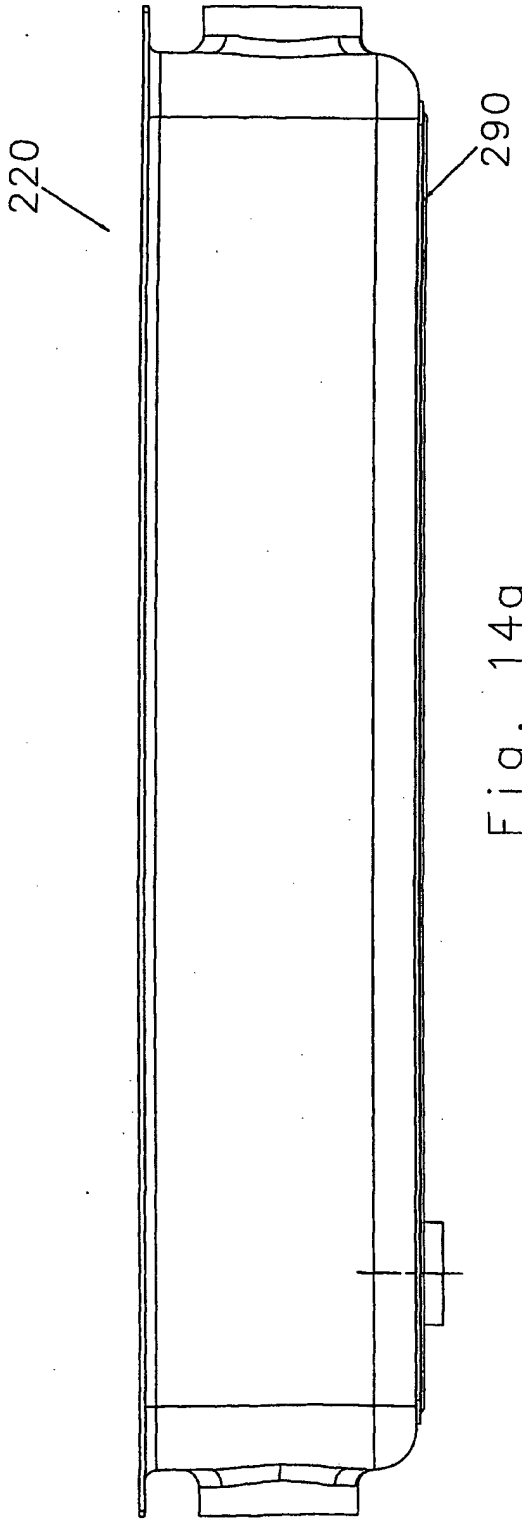


Fig. 14a

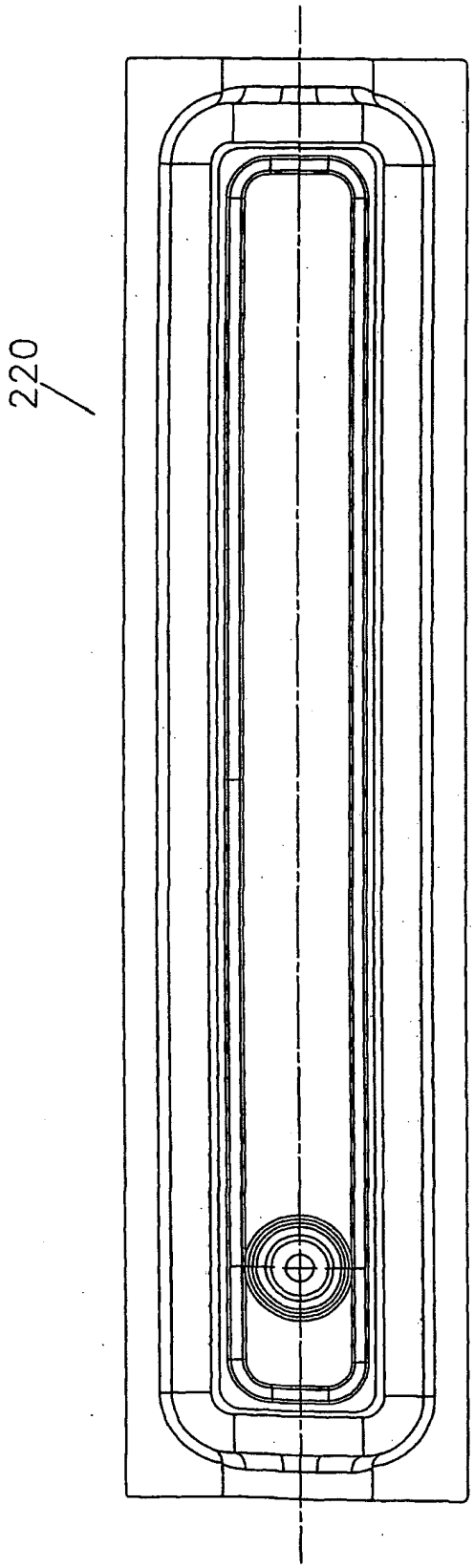


Fig. 14b

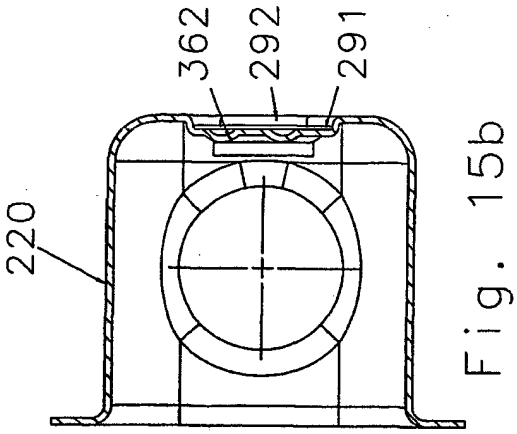


Fig. 15b

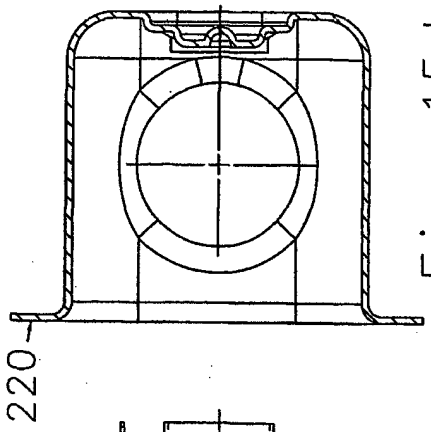


Fig. 15d

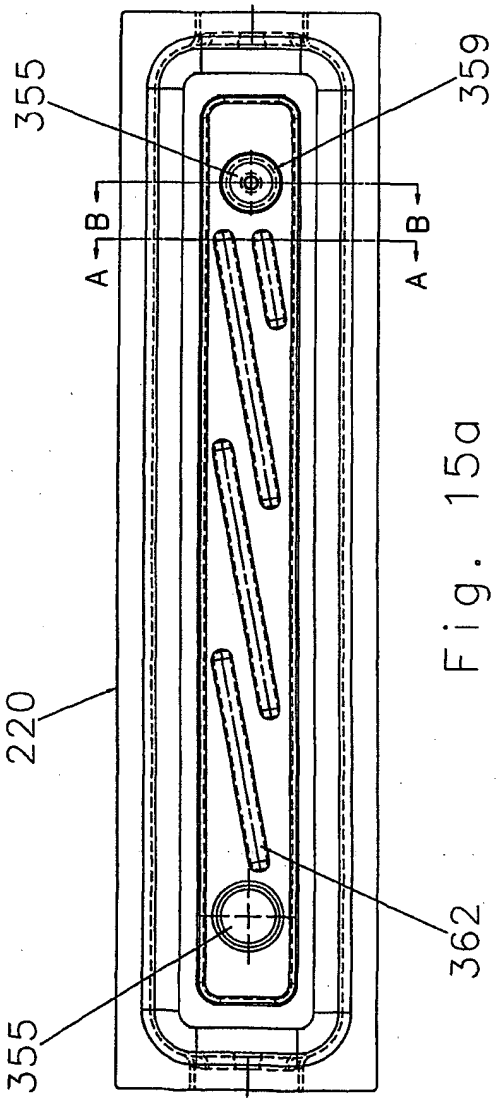


Fig. 15a

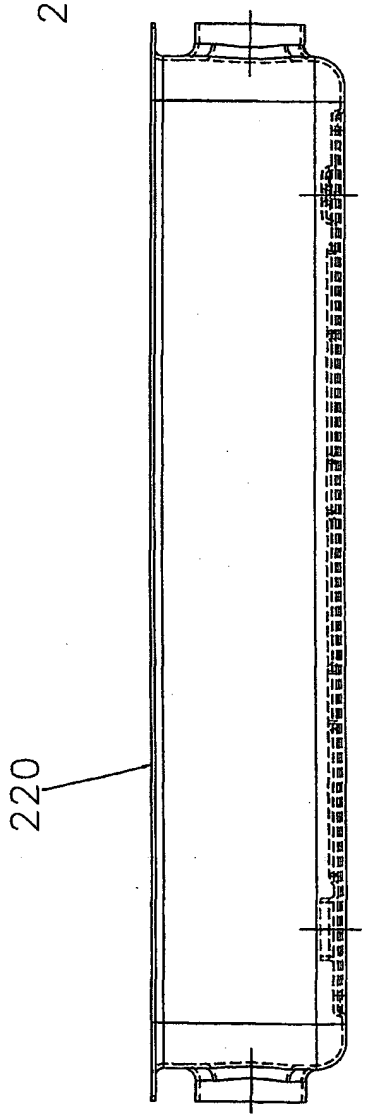


Fig. 15c

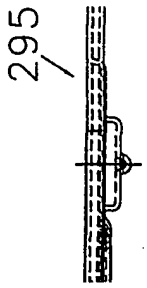


Fig. 16c

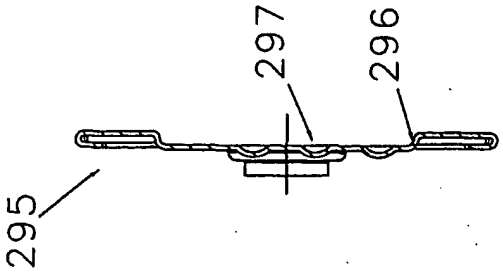


Fig. 16e

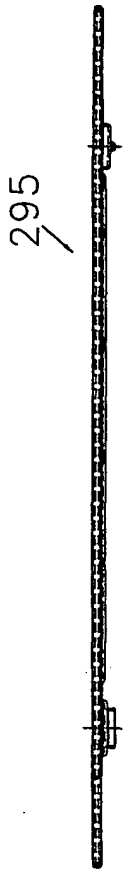


Fig. 16b

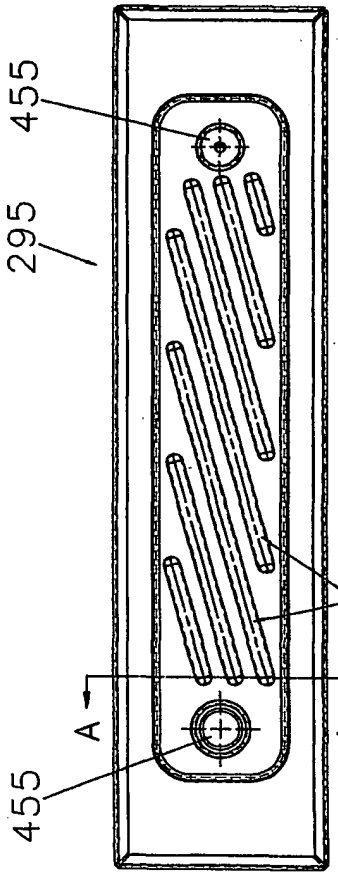


Fig. 16d

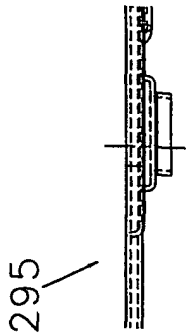


Fig. 16a

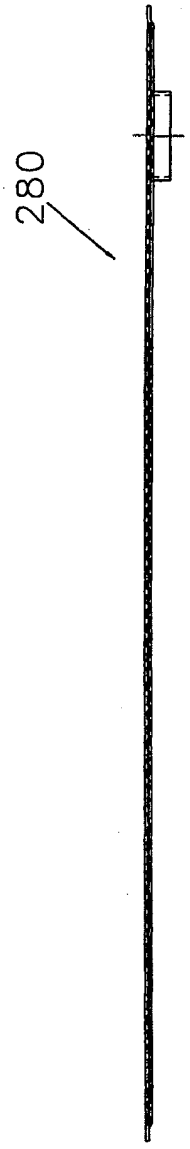


Fig. 17a

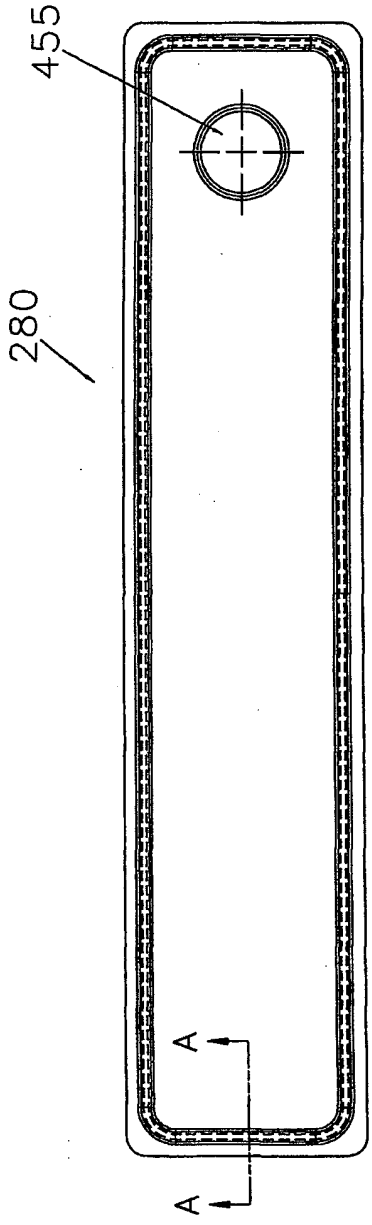
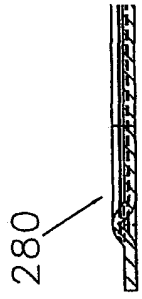


Fig. 17b



SECTION A-A

Fig. 17c

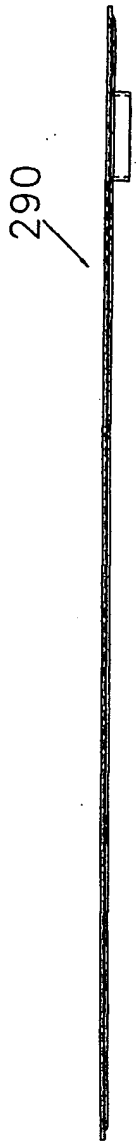


Fig. 18a

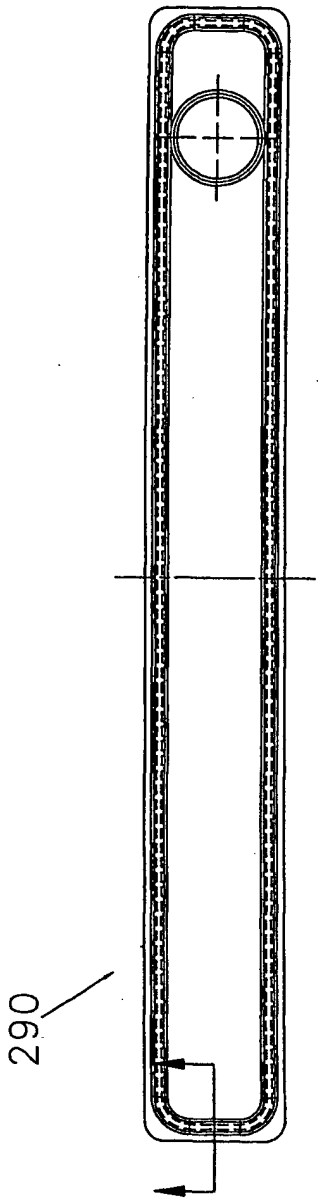


Fig. 18b

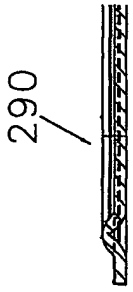


Fig. 18c

INTERNATIONAL SEARCH REPORT

In ional Application No
PCT/GB 01/02730

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28D9/00 F01N3/04 F28F3/04 F01N3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F28D F01N F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 992 756 A (MODINE MFG CO) 12 April 2000 (2000-04-12)	1-3,5,8, 9,11,14, 15,21, 24-26
Y	column 4, line 35 -column 5, line 65; figures 5,6	4,6,7
Y	---	10,16-20
Y	US 6 047 769 A (SHIMOYA MASAHIRO ET AL) 11 April 2000 (2000-04-11) column 6, line 45 -column 7, line 4; figures 1-5	4,6,7
Y	---	10,16-20
	FR 2 010 517 A (DELANEY GALLAY LTD) 20 February 1970 (1970-02-20) page 5, line 5 - line 33; figure 5	

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2001	13/11/2001

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